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(71) Applicant:
Matsushita Electric Industrial Co., Ltd.
Kadoma City, Osaka 571 (JP)

(72) Inventors:
- Karaorman, Murat
Santa Barbara, California 93108 (US)
- Junqua, Jean-Claude
Santa Barbara, California 93110 (US)

(74) Representative:
Franks, Robert Benjamin
Franks & Co.,
352 Omega Court,
Cemetery Road
Sheffield S11 8FT (GB)

(54) Natural language parsing method and apparatus

(57) A computer-implemented speech parsing method and apparatus for processing an input phrase. The method and apparatus include providing a plurality of grammars that are indicative of predetermined topics. A plurality of parse forests are generated using the grammars. Tags are associated with words preferably according to a scoring scheme utilizing the generated parse forests while parsing the input phrase. The tags that are associated with the words are used as a parsed representation of the input phrase.

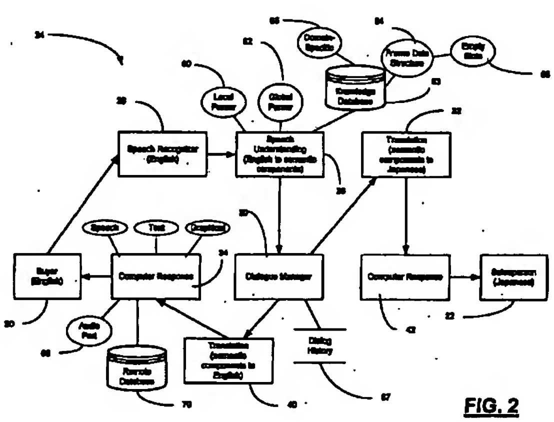

FIG. 2

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Description

Background and Summary of the Invention

[0001] The present invention relates to speech analysis, and more particularly to a computer-implemented natural language parser.

[0002] Understanding the meaning of a natural language sentence is the cornerstone of many fields of science with implications as broad ranging as from how humans interact with computers or machines to how they can interact with other intelligent agents, human or machine, through translation systems. The task becomes more complicated when the sentence is obtained using an automatic speech recognition system (ASR), where recognition errors such as insertions, omissions or substitutions can render the sentence less intelligible even to a human. Additional user-interface related factors might also introduce an element of un-naturalness to the speakers own utterance, so that the recognized sentence may contain the affects of users hesitations, pauses, repetitions, broken phrase or sentences.

[0003] Due to these factors, parsing natural language sentences occupies an important area in computer-implemented speech-related systems. However, current approaches for natural language parsers typically experience relatively sub-optimal robustness in handling the aforementioned errors of an automatic speech recognition system. The present invention overcomes the aforementioned disadvantages as well as other disadvantages.

[0004] In accordance with the teachings of the present invention, a computer-implemented speech parsing method and apparatus for processing an input phrase is provided. The method and apparatus include providing a plurality of grammars that are indicative of predetermined topics. A plurality of parse forests are generated using the grammars, and tags are associated with words in the input phrase using the generated parse forests. The tags that are associated with the words are used as a parsed representation of the input phrase.

[0005] For a more complete understanding of the invention, its objects and advantages, reference should be made to the following specification and to the accompanying drawings.

Brief Description of the Drawings

[0006]

Figure 1 is a block diagram depicting the computer-implemented components utilized to effect a dialog between at least two people with different languages;

Figure 2 is a block diagram depicting the components of the system of Figure 1 in more detail;

Figure 3 is a tag generation diagram depicting the application of the semantic tag generation process to an input sentence;

Figure 4 is a block diagram depicting the components of the local parser of the present invention;

Figure 5 is a tag generation diagram depicting the application of the semantic tag generation process to an input sentence;

Figure 6 is a parse tree diagram depicting a model for a parse tree for an input sentence;

Figure 7 is a parse tree diagram depicting multiple tags being generated as candidates during intermediate stages of local parsing;

Figure 8 is a process diagram depicting the output at different intervals for the present invention;

Figure 9 is a computer screen display of an exemplary cost grammar;

Figure 10 is a computer screen display of a parse forest generated for an input sentence;

Figure 11 is a graphical parse forest showing a partial representation in a graphical format of the parse forest in Figure 10;

Figure 12 is a flow chart depicting the operational steps associated with the present invention being utilized in an exemplary application; and

Figure 13 is a flow chart depicting the operational steps associated with processing an input sentence using the local parser of the present invention.

Description of the Preferred Embodiment

[0007] Figure 1 depicts a computer-implemented dialog continuous speech processing system for allowing two people who speak different languages to effectively communicate. In the non-limiting example of Figure 1, a buyer **20** wishes to communicate with salesperson **22** in order to purchase a piece of merchandise. The difficulty arises in that buyer **20** speaks only English while salesperson **22** speaks only Japanese.

[0008] The dialog speech processing system **24** of the present invention uses a speech recognizer **26** to transform the English speech of buyer **20** into a string of words. The string of words is read as text by a speech understanding

module 28 which extracts the semantic components of the string.

[0009] A dialog manager **30** determines whether a sufficient amount of information has been provided by buyer **20** based upon the semantic components determined by speech understanding module **28**. If a sufficient amount of information has been provided, dialog manager **30** allows translation module **32** to translate the buyers speech from the determined semantic components to Japanese. Translation module **32** translates the semantic components into Japanese and performs speech synthesis via computer response module **42** in order to vocalize the Japanese translation for salesperson **22** to hear.

[0010] Salesperson **22** then utilizes the dialog speech processing system **24** to respond to buyer **20**. Accordingly, a Japanese speech recognizer **36** and Japanese speech understanding module **38** respectively perform speech recognition of the speech of salesperson **22** if insufficient information has been provided by salesperson **22**.

[0011] If dialog manager **30** determines that an insufficient amount of information has been provided by buyer **20** for accomplishing a predetermined goal (such as purchasing a piece of merchandise), dialog manager **30** instructs a computer response module **34** to vocalize a response which will ask buyer **20** to provide the missing piece(s) of information.

[0012] The preferred embodiment is suitable for implementation in a hand-held computer device **43** where the device is a tool allowing the user to formulate his or her request in the target language. Such a portable hand-held device is well suited for making a ticket/hotel reservation in a foreign country, purchasing a piece of merchandise, performing location directory assistance, or exchanging money. The preferred embodiment allows the user to switch from one task to another by selecting on the hand-held device which task they would like to perform. In an alternate embodiment, a flash memory card which is unique to each task can be provided so that a user can switch from one task to another.

[0013] Figure 2 depicts components of the dialog speech processing system **24** in more detail. In particular, speech understanding module **28** includes a local parser **60** to identify predetermined relevant task-related fragments. Speech understanding module **28** also includes a global parser **62** to extract the overall semantics of the buyer's request.

[0014] The novel local parser **60** utilizes in the preferred embodiment small and multiple grammars along with several passes and an unique scoring mechanism to provide parse hypotheses. For example, the novel local parser recognizes according to this approach phrases such as dates, names of cities, and prices. If a speaker utters "get me a flight to Boston on January 23rd which also serves lunch", the local parser recognizes: "Boston" as a city name; "January 23rd" as a date; and "lunch" as being about a meal. The global parser assembles those items (city name, date, etc.) together and recognizes that the speaker wishes to take an airplane ride with certain constraints.

[0015] Speech understanding module **28** includes knowledge database **63** which encodes the semantics of a domain (i.e., goal to be achieved). In this sense, knowledge database **63** is preferably a domain-specific database as depicted by reference numeral **65** and is used by dialog manager **30** to determine whether a particular action related to achieving a predetermined goal is possible.

[0016] The preferred embodiment encodes the semantics via a frame data structure **64**. The frame data structure **64** contains empty slots **66** which are filled when the semantic interpretation of global parser **62** matches the frame. For example, a frame data structure (whose domain is purchasing merchandise) includes an empty slot for specifying the buyer-requested price for the merchandise. If buyer **20** has provided the price, then that empty slot is filled with that information. However, if that particular frame needs to be filled after the buyer has initially provided its request, then dialog manager **30** instructs computer response module **34** to ask buyer **20** to provide a desired price.

[0017] Preferably, computer response module **34** is multi-modal in being able to provide a response to a user via speech synthesis, text or graphical. For example, if the user has requested directions to a particular location, the computer response could display a graphical map with the terms on the map being translated by translation module **40**. Moreover, computer response module **40** can speak the directions to the user through audio part **68**. However, it is to be understood that the present invention is not limited to having all three modes present as it can contain one or more of the modes of the computer response module **34**.

[0018] Audio part **68** uses the semantics that have been recognized to generate a sentence in the buyers target language based on the semantic concept. This generation process preferably uses a paired dictionary of sentences in both the initial and target language. In an alternate embodiment, sentences are automatically generated based on per type sentences which have been constructed from the slots available in a semantic frame.

[0019] The frame data structure **64** preferably includes multiple frames which each in turn have multiple slots. One frame may have slots directed to attributes of a shirt, such as, color, size, and prices. Another frame may have slots directed to attributes associated with the location to which the shirt is to be sent, such as, name, address, phone number.

[0020] The following reference discusses global parsers and frames: R. Kuhn and R. D. Mod, *Spoken Dialogues with Computers (Chapter 14: Sentence Interpretation)*, Academic Press, Boston (1998).

[0021] Dialog manager **30** uses dialog history data file **67** to assist in filling in empty slots before asking the speaker for the information. Dialog history data file **67** contains a log of the conversation which has occurred through the device

of the present invention. For example, if a speaker utters "get me a flight to Boston on January 23rd which also serves lunch", the dialog manager **30** examines the dialog history data file **67** to check what city names the speaker may have mentioned in a previous dialog exchange. If the speaker had mentioned that he was calling from Detroit, then the dialog manager **30** fills the empty slot of the source city with the city name of "Detroit". If a sufficient number of slots have been filled, then the present invention will ask the speaker to verify and confirm the flight plan. Thus, if any assumptions made by the dialog manager **30** Through the use of dialog history data file **67** prove to be incorrect, then the speaker can correct the assumption.

[0022] In another alternate embodiment computer response module **34** is instructed by dialog manager **30** to perform a search on the remote database **70** in order to provide buyer **20** with information about that piece of merchandise. In this non-limiting example, dialog manager **30** can instruct computer response module **34** to search the store's remote database **70** for the price range of the merchandise for which the buyer **20** is interested. The alternate embodiment substantially improves the quality of the dialog between buyer **20** and salesperson **22** by providing information to buyer **20** so that buyer **20** can formulate a more informed request to salesperson **22**.

[0023] Dialog manager **30** assumes an integral role in the dialog by performing a back-and-forth dialog with buyer **20** before buyer **20** communicates with salesperson **22**. In such a role, dialog manager **30** using the teachings of the present invention is able to effectively manage the turn-taking aspect of a human-like back-and-forth dialog. Dialog manager **30** is able to make its own decision about which direction the dialog with buyer **20** will take next and when to initiate when a new direction will be taken.

[0024] For example, if buyer **20** has requested a certain type of shirt within a specified price range, dialog manager **30** determines whether such a shirt is available within that price range. Such a determination is made via remote database **70**. In this example, dialog manager **30** determines that such a shirt is not available in the buyers price range, however, another type of shirt is available in that price range. Thus, dialog manager **30** can determine whether a particular action or goal of the buyer is feasible and assist the buyer to accomplish that goal.

[0025] The present invention analyzes and extracts semantically important and meaningful topics from a loosely structured, natural language text which may have been generated as the output of an automatic speech recognition system (ASR) used by a dialogue or speech understanding system. The present invention translates the natural language text input to a new representation by generating well-structured tags containing topic information and data, and associating each tag with the segments of the input text containing the tagged information. In an alternate embodiment, tags are generated as a separate list, or as a semantic frame.

[0026] Figure 3 depicts a non-limiting example of the role of the local parser of the present invention in a speech understanding system such as, in an automated online travel reservation specialist with a speech interface. The following topics can be potential targets for the present invention: flight arrival and departure times, and dates possibly with ranges and constraints; city-names involved in the flight; fare/cost information involving currency amounts; class of seats; meal information; flight-numbers; names of airlines; the stop-overs of the flight, etc.

[0027] The example includes a possible input sentence **100** as generated from a continuous speech recognition system and containing recognition mistakes. The corresponding output **102** is a possible interpretation by the present invention where three tags have been generated, one corresponding to city-names **104**, one to time **106**, and one to date **108**.

[0028] Robustness is a feature of the present invention as the input can contain grammatically incorrect English sentences, such as in the example above, due to the following reasons: the input to the recognizer is casual, dialog style, natural speech and can contain broken sentences, partial phrases; the speech recognition may introduce insertion, omission, or mis-recognition errors even when the speech input is considered correct. The present invention deals robustly with all types of input and extracts as much information as possible.

[0029] Figure 4 depicts the different components of the novel local parser **60** of the present invention. The present invention preferably utilizes generalized parsing techniques in a multi-pass approach as a fixed-point computation. Each topic is described as a context-sensitive LR (left-right and rightmost derivation) grammar, allowing ambiguities. The following are references related to context-sensitive LR grammars: A. Aho and J. D. Ullman, *Principles of Compiler Design*, Addison Wesley Publishing Co., Reading, Massachusetts (1977); and N. Tomita, *Generalized LR Parsing*, Kluwer Academic Publishers, Boston, Massachusetts (1991).

[0030] At each pass of the computation, a generalized parsing algorithm is used to generate preferably all possible (both complete and partial) parse trees independently for each targeted topic. Each pass potentially generates several alternative parse-trees, each parse-tree representing a possibly different interpretation of a particular topic. The multiple passes through preferably parallel and independent paths result in a substantial elimination of ambiguities and overlap among different topics. The present invention is a systematic way of scoring all possible parse-trees so that the (N) best candidates are selected utilizing the contextual information present in the system.

[0031] Local parsing system **60** is carried out in three stages: lexical analysis **120**; parallel parse-forest generation for each topic (for example, generators **130** and **132**); and analysis and synthesis of parsed components as shown generally by reference numeral **134**. The preferred embodiment depicts the structure for the inputs to and outputs from the

local parser in Exhibit A below.

Lexical analysis:

[0032] A speaker utters a phrase that is recognized by an automatic speech recognizer **117** which generates input sentence **118**. Lexical analysis stage **120** identifies and generates tags for the topics (which do not require extensive grammars) in input sentence **118** using lexical filters **126** and **128**. These include, for example, city-names; class of seats; meal information; names of airlines; and information about stop-overs. A regular-expression scan of the input sentence **118** using the keywords involved in the mentioned exemplary tags is typically sufficient at this level. Also, performed at this stage is the tagging of words in the input sentence that are not part of the lexicon of particular grammar. These words are indicated using an X-tag so that such noise words are replaced with the letter "X".

Parallel parse-forest generation:

[0033] The present invention uses a high-level general parsing strategy to describe and parse each topic separately, and generates tags and maps them to the input stream. Due to the nature of unstructured input text **118**, each individual topic parser preferably accepts as large a language as possible, ignoring all but important words, dealing with insertion and deletion errors. The parsing of each topic involves designing context-sensitive grammar rules using a meta-level specification language, much like the ones used in LR parsing. Examples of grammars include grammar A **140** and grammar B **142**. Using the present invention's approach, topic grammars **140** and **142** are described as if they were an LR-type grammar, containing redundancies and without eliminating shift and reduce conflicts. The result of parsing an input sentence is all possible parses based on the grammar specifications.

[0034] Generators **130** and **132** generate parse forests **150** and **152** for their topics. Tag-generation is done by synthesizing actual information found in the parse tree obtained during parsing.

[0035] Figure 4 depicts tag generation via tag and score generators **160** and **162** which respectively generate tags **164** and **166**. Each identified tag also carries information about what set of input words in the input sentence are covered by the tag. Subsequently the tag replaces its cover-set. In the preferred embodiment, context information **167** is utilized for tag and score generations, such as by generators **160** and **162**. Context information **167** is utilized in the scoring heuristics for adjusting weights associated with a heuristic scoring factor technique that is discussed below. Context information **167** preferably includes word confidence vector **168** and dialogue context weights **169**. However, it should be understood that the present invention is not limited to using both word confidence vector **168** and dialogue context weights **169**, but also includes using one to the exclusion of the other, as well as not utilizing context information **167** within the present invention.

[0036] Automatic speech recognition process block **117** generates word confidence vector **168** which indicates how well the words in input sentence **118** were recognized. Dialog manager **30** generates dialogue context weights **169** by determining the state of the dialogue. For example, dialog manager **30** asks a user about a particular topic, such as, what departure time is preferable. Due to this request dialog manager **30** determines that the state of the dialogue is time-oriented. Dialog manager **30** provides dialogue context weights **169** in order to inform the proper processes to more heavily weight the detected time-oriented words.

Synthesis of Tag-components:

[0037] The topic spotting parser of the previous stage generates a significant amount of information that needs to be analyzed and combined together to form the final output of the local parser. The present invention is preferably as "aggressive" as possible in spotting each topic resulting in the generation of multiple tag candidates. Additionally in the presence of numbers or certain key-words, such as "between", "before", "and", "or", "around" etc., and especially if these words have been introduced or dropped due to recognition errors it is possible to construct many alternative tag candidates. For example, the input sentence **220** in Figure 5 could have been a result of insertion or deletion errors. The combining phase of the present invention determines which tags form a more meaningful interpretation of the input. The present invention defines heuristics and makes a selection based on them using a N-Best candidate selection process. Each generated tag corresponds to a set of words in the input word string, called the tag's cover-set.

[0038] A heuristic is used that takes into account the cover-sets of the tags used to generate a score. The score roughly depends on the size of the cover-set, the sizes in the number of the words of the gaps within the covered items, and the weights assigned to the presence of certain keywords. In the preferred embodiment, ASR-derived confidence vector and dialog context information are utilized to assign priorities to the tags. For example applying cost-tags parsing first potentially removes cost-related numbers that are easier to identify uniquely from the input stream, and leaves fewer numbers to create ambiguities with other tags. Preferably, dialog context information is used to adjust the priorities.

N-Best Candidates Selection

[0039] With reference back to Figure 4, at the end of each pass, an N-best processor **170** selects the N-best candidates based upon the scores associated with the tags and generates the topic-tags, each representing the information found in the corresponding parse-tree. Once topics have been discovered this way, the corresponding words in the input can be substituted with the tag information. This substitution transformation eliminates the corresponding words from the current input text. The output **180** of each pass is fed-back to the next pass as the new input, since the substitutions may help in the elimination of certain ambiguities among competing grammars or help generate better parse-trees by filtering out overlapping symbols.

[0040] Computation ceases when no additional tags are generated in the last pass. The output of the final pass becomes the output of the local parser to global parser **62**. Since each phase can only reduce the number of words in its input and the length of the input text is finite, the number of passes in the fixed-point computation is linearly bounded by the size of its input.

[0041] The following novel scoring factors are used to rank the alternative parse trees based on the following attributes of a parse-tree:

- Number of terminal symbols.
- Number or non-terminal symbols.
- The depth of the parse-tree.
- The size of the gaps in the terminal symbols.
- ASR-Confidence measures associated with each terminal symbol.
- Context-adjustable weights associated with each terminal and non-terminal symbol.

Each path preferably corresponds to a separate topic that can be developed independently, operating on a small amount of data, in a computationally inexpensive way. The architecture of the present invention is flexible and modular so incorporating additional paths and grammars, for new topics, or changing heuristics for particular topics is straight forward, this also allows developing reusable components that can be shared among different systems easily.

[0042] Figure 6 provides a non-limiting depiction of a tree in relation to a discussion to the tag scoring heuristics. Figure 6 depicts an input string **250** and a sample parse-tree **252**. The parse-tree rooted as St **254** identifies the subsequence {w3, w4, w7, w8, w10}, as a possible parse. This parse has 5 terminal symbols {w3, w4, w7, w8, w10}, with gaps between w4 & w7 (size=2) and between w8 and w10 (size= 1), or total gapsize of 3. Parse tree **252** has four non-terminals: St **254**, NT_a **256**, NT_b **258**, and NT_c **260**. The depth of parse tree **252** is three due to the traversal from St **254** to NT_f **258** to NT_a **256** to W3.

[0043] A possible score for this parse is: #Terminals*10 —(GapSize*1.5)—Depth + #Non-terminals = 50 4.5-3+4 = 46.5

[0044] The present invention also includes utilizing non-uniform weights which can be assigned to the non-terminal and terminal nodes. Also, confidence measures are preferably utilized to adjust the weights of one or more of the scoring factors. For example, a likelihood ratio algorithm can be utilized to compute confidence scores (see, for example, the following reference: R. Sukkar and Chin-Hui Lee, *Vocabulary Independent Discriminative Utterance Verification for Non-Key Word Rejection in Sub-Word Based Speech Recognition,* IEEE Transactions on Speech and Audio Processing, Vol.4, No. 6, pages 420-29 (1996)).

[0045] Figure 7 provides another non-limiting depiction of a tree in relation to a discussion to the scoring heuristics. Five parse trees are shown at reference numerals **270,272,274,276,** and **278**. With respect to the five possible parse trees and corresponding tags shown in Figure 7, the following scoring approach is used:

#	Tag	#words	#NT	Depth	Gap	Score	Rank
1	*Time[> 19:00]*	3	2	2	7	30+2-2-10.5 = 19.5	4
2	*Time[> 19:10]*	4	3	3	10	40+3-3-15 = 25.0	2
3	*Time[> 7:00]*	2	1	1	1	20+1-1-1.5 =18.5	5
4	*Time[> 7:10]*	3	2	2	4	30+2-2-6 = 20.0	3
5	*Date[~6/10]*	3	2	2	0	30+2-2-0 =30	1

[0046] The score based system results in Tag#5 being picked as the best candidate for Date targets, this selection

eliminates Tag#2 and Tag#4 from further consideration due to the overlap with Tag#1 lexicon. This leaves the parse for Tag#1 as the next best parse, so Tags #5 and #1 are selected.

[0047] The present invention utilizes multiple-passes as illustrated in Figure 8. At reference numeral **290**, outputs of the present invention are depicted at different passes in processing input sentence **294**. Parse tree forest **296** is generated during the first pass and helps to generate first pass output **298**. First pass output **298** has associated time tag **300** with the words of input sentence **294** "Five thirty pm".

[0048] First pass output **298** is used as an input for a second pass processing of input sentence **294**. Parse forest **302** is generated during processing of the second pass and results in a cost tag **304** being generated. In one embodiment of the present invention, the reason why the first pass processing did not parse the hundred dollars part of input sentence **294** is due to N-best tag selection and combining block **170** of Figure 4. During the first phase, due to lexical filtering and aggressive parsing, the best cost parse is "five hundred dollars", and the best time parse is parse tree forest **296** for "after five thirty p-m". Since the word "five" is shared, the selection process invalidates the best cost parse and generates the time tag for "five thirty p-m". However, the end of the second pass results in a filtered string **308** which generates the cost tag **304** successfully.

Grammar

[0049] In the preferred embodiment, each topic is expressed as a generalized LR(0) grammar using the following syntax:

```
TopicGrammar = Rule+.
        Rule = "*" ID "." |
               ID "." |
               ID "=" ID* ("|" ID*)* "." |


               ID ":" ID+ ".".
```

[0050] The grammar syntax informally states that the grammar is expressed as a series of grammar rules, where each grammar rule either describes a context-sensitive substitution rule for a terminal or a non-terminal grammar symbol.

[0051] Figure 9 depicts an exemplary grammar for parsing the cost involving dollar or yen amounts. The first rule ⟨* COST.⟩ **320** declares the root non-terminal symbol to be COST.

[0052] Each subsequent rule of the form ⟨A = X Y Z.⟩ specifies a non-terminal symbol, A, and a substitution rule where the symbol A can be substituted in a rightmost derivation by the three right hand side grammar symbols, X Y Z, each of which is either a terminal or non-terminal symbol. For example, the rule **324**:

```
C_Gen = C_Num |
        C_Num C_Currency.
```

defines C_Gen as a non-terminal that can be reduced with either a number (C_Num) or a number followed by a currency symbol (C_Currency). Terminal symbols are defined using the ⟨t: s1 s2.⟩ For example, the rule **328**:

c_yen: yen yens.

defines c_yen to be a terminal symbol matching the "yen" or "yens" as a next token in the input stream.

[0053] The cost grammar matches all words that are not defined as terminals under the X rule. A lexical filter is used to convert all input words that are not relevant to COST rules with the word "x". Accordingly, the X rule matches one or more consecutive "x"s.

[0054] Figure 10 shows a non-limiting example of parsing the sentence **400**: "flights under five hundred dollars." Each line represents the application of a grammar rule, for example at reference numeral **404**:

C_Tens_2_3=c_num_2_3.

represents a node in the parse forest where the grammar symbol C_Tens covers the range [2-3], i.e. the word "five". Similarly line **408**:

c_qualifier_1_2: "under.

represents terminal symbol c_qualifier matching the range [1-2], i.e. the word "under. The root symbol rule **412**, COST_0_5 covers the entire range signalling a successful parse which yielded a unique parse for the entire input. Other root symbols rules are depicted which have their own parse trees shown in Figure 10. For example, Figure 10 depicts a parse tree for root symbol **437**. If multiple parses are used, a rule contains the alternatives shown with "|" s. Also notice in a non-limiting manner how the first word, "flights", is skipped over by the X rule.

[0055] Figure 11 shows a partial graphical tree depiction of the data of Figure 10. For example, root symbol rule is depicted by reference numeral **412** on Figure 11.

<u>**Tag Generation:**</u>

[0056] The preferred tag generation method uses a parse forest, and generates the tags as specified by the output specifications. The tag generation algorithm (called reduce) uses a synthesis and inheritance approach in order to construct each tag utilizing the information found in the parse tree (note: the usage of the name "reduce" herein is separate and different from the term reduce (as in shift/reduce actions) used in the LR parsing literature). The reduce algorithm used by the tag generation method operates as follows:

Input: node: α_i_j (any node in the parse forest.)

[0057]

1. If α_i_j is a terminal rule, return the right-hand-side (which is a token at the input stream at position *i*) either unchanged, or by assigning it a meaning - for example applying a conversion from ascii to numeric for a digit, etc.,)

2. *remove all the X-rules* from the right-hand-side, yielding a rule of the form

$$\alpha\_i\_j = \beta_0\_i_0\_j_0\, \beta_1\_i_1\_j_1 \cdot \beta_k\_i_k\_j_k\,.$$

where $\beta \neq X$.

3. *Evaluate new attribute*, α, for α_i_j by concatenating results from reducing the terms on the right-hand-side, i.e.:

$$\alpha\_i\_j.\alpha = \Sigma_{i=0..k}\, \textbf{reduce}(\beta_i\_i_i\_j_i)$$

where: Σ is a concatenation operator.

4. *Inherit all the attributes* from each reduced term on the righthand-side.
for each term, $\beta_i\_i_i\_j_i$ in the right-hand-side

for each attribute, $\phi \in \beta_i\_i_i\_j_i$. *AttrList*

add ϕ to the node's attribute list:

$$\alpha\_i\_j.AttrList \cup = \phi$$

inherit the attribute value:

$$\alpha\_i\_j.\phi = \beta_{i}\_i_{i}\_j_{i}.\phi$$

5. If necessary *generate new attributes* for α_i_j possibly utilizing the inherited and computed attributes. All new attributes are inherited by the parent nodes, all the way up to the root node. This is the general mechanism by which we can construct and initialize the tag structures.

[0058] Figure 12 depicts operation of the present invention within an exemplary application of a buyer attempting to buy a particular shirt while speaking in a first language to a seller who speaks in a second language. The start indication block **500** indicates process block **504** is to be processed. At process block **504**, the buyer speaks in a first language about a particular shirt. At process block **508**, the buyer's speech is recognized and predetermined parts of the buyers speech is determined via the local parser of the present invention at process block **512**.

[0059] Process block **516** determines the semantic portions of the buyer's speech via a global parser. Process block **520** translates the determined semantic parts to a second language which is then vocalized at process block **524**. At process block **528**, any response from the salesperson or buyer is processed according to the present invention. Processing terminates at process block **532**.

[0060] Figure 13 depicts the operational steps associated with the multi-pass architecture of the local parser of the present invention. Start indication block **550** indicates that process block **554** is to be executed wherein an input sentence is received. Process block **567** performs automatic speech recognition for the input sentence.

[0061] Iteration block **566** performs for each grammar the following steps. Preferably, the processing for each grammar is performed substantially concurrently with the processing for a second grammar. Process block **570** utilizes a lexical filter on the input sentence using the grammar as selected by iteration block **566**.

[0062] Process block **574** generates a parse forest using the selected grammar, and process block **578** generates tags for the input sentence using confidence vectors from process block **557** and using dialogue context weights from process block **599** (if available from previous processing of the dialogue manager). It is to be understood, however, that the present invention is not limited to using context-related data at this stage in processing, but also includes utilizing no context information at this stage.

[0063] Process block **582** generates a score for the tags that were generated at process block **578**. Process block **586** selects the N-best tags based upon the score generated by process block **582**. Process block **590** generates the tag output, and iteration terminator block **594** repeats the process until each grammar has been utilized.

[0064] If each grammar has been utilized for a particular pass, then decision block **598** inquires whether any additional tags have been generated. If additional tags have been generated, then processing continues at iteration block **566**. If no additional tags were generated, then processing continues at process block **599**. At process block **599**, global parsing is performed, and then the dialog manager processing is performed wherein context weights are determined that could be used, if needed, in the next processing of an input sentence. Processing terminates at end block **602**.

[0065] While the invention has been described in its presently preferred form, it is to be understood that there are numerous applications and implementations for the present invention. Accordingly, the invention is capable of modification and changes without departing from the spirit of the invention as set forth in the appended claims.

EXHIBIT A

Input: Ascii-text string, s, containing a sequence of white-space seperated *words*, w_i, without any punctuation marks. The words are comprised of lower-case letters of English alphabet and the single-quote character. [note: no digits]

```
where s = w0 w1 ... wn
      w = [a-z']+
```

Output: Ascii-text string, out, containing a sequence of white-space seperated *words* or *tags* without punctuation marks.

```
where out = wt0 wt1 ... wtm
      wt = w|t
      w = [a-z']+
      t = dateTag |
          timeTag |
          costTag |
          flightNumTag |
          cityNameTag |
          airlineTag |
          stopTag |
          classTag |
          mealTag |
          typeTag

      dateTag = DATE[d] |                 ; plain date
                DATE[d-d] |               ; date range
                DATE[< d] |               ; before date
                DATE[> d] |               ; after date
                DATE[~ d] |               ; around date
                DATE[d] ||DATE[d] |       ; alternative dates
                DATE[MIN()]               ; earliest date

            d = dy/mo |                   ; date=day &
month
```

```
                X/mo                              ; any day of the month
             dy = 1|2|3| ... | 31
             mo = 1|2| ... 12

        timeTag = TIME[t] |                       ; plain time
                  TIME[t-t] |                     ; time range
                  TIME[< t] |                     ; before time
                  TIME[> t] |                     ; after time
                  TIME[~ t] |                     ; around time
                  TIME[t]||TIME[t]                ; alternative times
                  TIME[MIN()]                     ; earliest
                  TIME[MAX()]                     ; latest

              t = hrs:min                         ; time=hrs:minutes

            hrs =      1|2|3| ... | 24
            min = 01|02| ... 59

        costTag = COST[c] |                       ; plain cost
                  COST[c-c] |                     ; cost range
                  COST[< c] |                     ; under the amount
                  COST[> c] |                     ; over the amount
                  COST[- c] |                     ; around cost
                  COST[MIN()]                     ; cheapest
                  COST[MAX()]                     ; most expensive

              c = amountY |                       ; amount in yens
                  amount$                         ; amount in dollars

         amount = 1|2|3| ... | 99999

   flightNumTag = FNUM[fnum]
           fnum = 1|2|3| ....| 9999

    cityNameTag =  CITY[cityName]

       cityName = ATLANTA | BALTIMORE BANGKOK | BOSTON |
                  CHICAGO | DALLAS | DENVER | HONG KONG|
                  HOUSTON | LOS_ANGELES | L_A | MIAMI |
```

```
                NEW_ORLEANS | NEW_YORK |
        NEW_YORK_CITY|
                OAKLAND | OSAKA | PHILADELPHIA | SEOUL
        |
                PITTSBURGH | SAN_FRANCISCO |
        WASHINGTON|
                SINGAPORE | TOKYO| TORONTO |
        VANCOUVER|

airlineTag =    CITY[airlineName]

    airlineName = AMERICAN_AIRLINES | U_S_AIR
|
                  JAPAN_AIRLINES |
    CONTINENTAL |
                  UNITED | SINGAPORE_AIRLINES

stopTag =       STOP[> 0] |                ; any # of
stops
                STOP[= 0]                  ; non-stop

classTag =      CLAS[class]                ; class
   class =      first | business | economy

mealTag =       MEAL[meal]                 ; meal info
   meal =       dinner | lunch | breakfast

typeTag =       TYPE[oneway] | TYPE[round trip]
```

Claims

1. A computer-implemented speech parsing method for processing an input phrase, comprising the steps of:

   (a) providing a plurality of grammars indicative of predetermined topics;
   (b) generating a plurality of parse forests related to said input phrase using said grammars;
   (c) associating tags with words in said input phrase using said generated parse forests; and
   (d) using said tags associated with said words as a parsed representation of said input phrase.

2. The speech parsing method of Claim 1 further comprising the step of:

   performing said step (b) a plurality of iterations so that each iteration produces alternate parse forests.

3. The speech parsing method of Claim 1 wherein said step (b) is performed substantially concurrently for each of said grammars.

4. The speech parsing method of Claim 3 further comprising the step of:

performing said step (b) a plurality of iterations wherein each iteration produces alternate parse forests with respect to each of said grammars.

5. The speech parsing method of Claim 1 further comprising the steps of:

generating scores for said tags; and
selecting tags for use in said parsed representation based upon said generated scores.

6. The speech parsing method of Claim 5 further comprising the step of:

generating scores for said tags based upon attributes of said parse forests.

7. The speech parsing method of Claim 6 further comprising the step of:

generating scores for said tags based upon score based factors selected from the group consisting of number of terminals, gap size, depth, number of non-terminals, and combinations thereof.

8. The speech parsing method of Claim 7 further comprising the step of:

weighting at least two of said factors differently.

9. The speech parsing method of Claim 8 further comprising the step of:

using context information to weigh at least two of said factors differently.

10. The speech parsing method of Claim 9 further comprising the steps of:

generating a word confidence vector for said input phrase substantially during speech recognition of said input phrase; and
weighting at least two of said factors differently based upon said generated word confidence vector.

11. The speech parsing method of Claim 10 further comprising the steps of:

generating a request for information related to a predetermined topic;
generating dialogue context weights based upon said generated request for information; and
weighting at least two of said factors differently based upon said generated dialogue context weights.

12. The speech parsing method of Claim 9 further comprising the steps of:

generating a request for information related to a predetermined topic;
generating dialogue context weights based upon said generated request for information; and
weighting at least two of said factors differently based upon said generated dialogue context weights.

13. The speech parsing method of Claim 9 further comprising the steps of:

using said context information processor substantially in parallel to performing said step (b).

14. The speech parsing method of Claim 1 further comprising the steps of:

generating scores for said tags; and
selecting N-best tags for use in said parsed representation based upon said generated scores.

15. The speech parsing method of Claim 14 further comprising the steps of:

performing said steps (b) and (c) a plurality of iterations; and
using said selected N-best tags of a first iteration as input related to processing said steps (b) and (c) of a sec-

ond iteration.

16. The speech parsing method of Claim 1 wherein said tags are indicative of said topics of said grammars

17. The speech parsing method of Claim 1 wherein said input phrase is grammatically incorrect with respect to at least a portion of said input phrase, said method further comprising the steps of:

generating a plurality of parse forests related to said grammatically incorrect input phrase using said grammars;
associating tags with words in said grammatically incorrect input phrase using said generated parse forests; and
using said tags associated with said words as a parsed representation of said grammatically incorrect input phrase.

18. The speech parsing method of Claim 1 wherein said grammars are based upon left-right context-sensitive grammars.

19. The speech parsing method of Claim 1 wherein said grammars are based upon left-right context-sensitive grammars and contain ambiguities.

20. The speech parsing method of Claim 1 further comprising the steps of:

filtering said input phrase via lexical filters; and
generating said plurality of parse forests based upon said filtered input phrase.

21. The speech parsing method of Claim 1 further comprising the step of:

extracting semantic components of said input phrase based upon said tags that are associated with said words.

22. The speech parsing method of Claim 1 further comprising the step of:

providing a global parser to extract said semantic components from said input phrase based upon said tags that are associated with said words.

23. The speech parsing method of Claim 22 further comprising the step of:

managing based upon said extracted semantic components the exchange of dialogue between a speech recognizer device and a user.

24. The speech parsing method of Claim 22 further comprising the step of:

managing based upon said extracted semantic components the exchange of dialogue between two users who speak different languages.

25. A computer-implemented speech parsing apparatus for processing an input phrase, comprising:

a plurality of grammars indicative of predetermined topics;
a parse forest generator for generating a plurality of parse forests related to said input phrase using said grammars; and
a tag generator for associating tags with words in said input phrase using said generated parse forests, wherein said tags associated with said words are used as a parsed representation of said input phrase.

26. The speech parsing apparatus of Claim 25 wherein said parse forest generator is executed a plurality of iterations such that each iteration produces alternate parse forests.

27. The speech parsing apparatus of Claim 25 wherein said parse forest generator is executed a plurality of iterations such that each iteration produces alternate parse forests with respect to each of said grammars.

28. The speech parsing apparatus of Claim 25 further comprising:

a tag score generator for generating scores for said tags; and
a tag selector for selecting tags for use in said parsed representation based upon said generated scores.

29. The speech parsing apparatus of Claim 28 wherein said tag score generator generates scores for said tags based upon attributes of said parse forests.

30. The speech parsing apparatus of Claim 29 wherein said tag score generator generates scores for said tags based upon score based factors selected from the group consisting of number of terminals, gap size, depth, number of non-terminals, and combinations thereof.

31. The speech parsing apparatus of Claim 30 wherein said tag score generator weights at least two of said factors differently.

32. The speech parsing apparatus of Claim 31 wherein said tag score generator uses context information to weight at least two of said factors differently.

33. The speech parsing apparatus of Claim 32 further comprising:

a speech recognition module for performing speech recognition of said input phrase and for generating a word confidence vector for said input phrase substantially,
said tag score generator weighting at least two of said factors differently based upon said generated word confidence vector.

34. The speech parsing apparatus of Claim 33 further comprising:

a dialogue manager for generating a request for information related to a predetermined topic, said dialogue manager generating dialogue context weights based upon said generated request for information,
said tag score generator weighting at least two of said factors differently based upon said generated dialogue context weights.

35. The speech parsing apparatus of Claim 32 further comprising:

a dialogue manager for generating a request for information related to a predetermined topic, said dialogue manager generating dialogue context weights based upon said generated request for information,
said tag score generator weighting at least two of said factors differently based upon said generated dialogue context weights.

36. The speech parsing apparatus of Claim 25 further comprising:

a tag score generator for generating scores for said tags; and
a tag selector for selecting N-best tags for use in said parsed representation based upon said generated scores.

37. The speech parsing apparatus of Claim 14 wherein said parse forest generator and said tag generator are executed a plurality of iterations, said selected N-best tags of a first iteration are used as input to said parse forest generator and said tag generator during a second iteration.

38. The speech parsing apparatus of Claim 25 wherein said tags are indicative of said topics of said grammars

39. The speech parsing apparatus of Claim 25 wherein said input phrase is grammatically incorrect with respect to at least a portion of said in put phrase, said parse forest generators generating a plurality of parse forests related to said grammatically incorrect input phrase using said grammars, said tag generator associating tags with words in said grammatically incorrect input phrase using said generated parse forests, said tags being associated with said words as a parsed representation of said grammatically incorrect input phrase.

40. The speech parsing apparatus of Claim 25 wherein said grammars are based upon left-right context-sensitive

grammars.

41. The speech parsing apparatus of Claim 25 wherein said grammars are based upon left-right context-sensitive grammars and contain ambiguities.

42. The speech parsing apparatus of Claim 25 further comprising:

a lexical filter for filtering said input phrase, said parse forest generator generating said plurality of parse forests based upon said filtered input phrase.

43. The speech parsing apparatus of Claim 25 further comprising:

a semantic extractor for extracting semantic components of said input phrase based upon said tags that are associated with said words.

44. The speech parsing apparatus of Claim 43 further comprising:

a global parser to extract said semantic components from said input phrase based upon said tags that are associated with said words.

45. The speech parsing apparatus of Claim 44 further comprising:

a dialogue manager for managing based upon said extracted semantic components the exchange of dialogue between a speech recognizer device and a user.

46. The speech parsing apparatus of Claim 44 further comprising:

a dialogue manager for managing based upon said extracted semantic components the exchange of dialogue between two users who speak different languages.

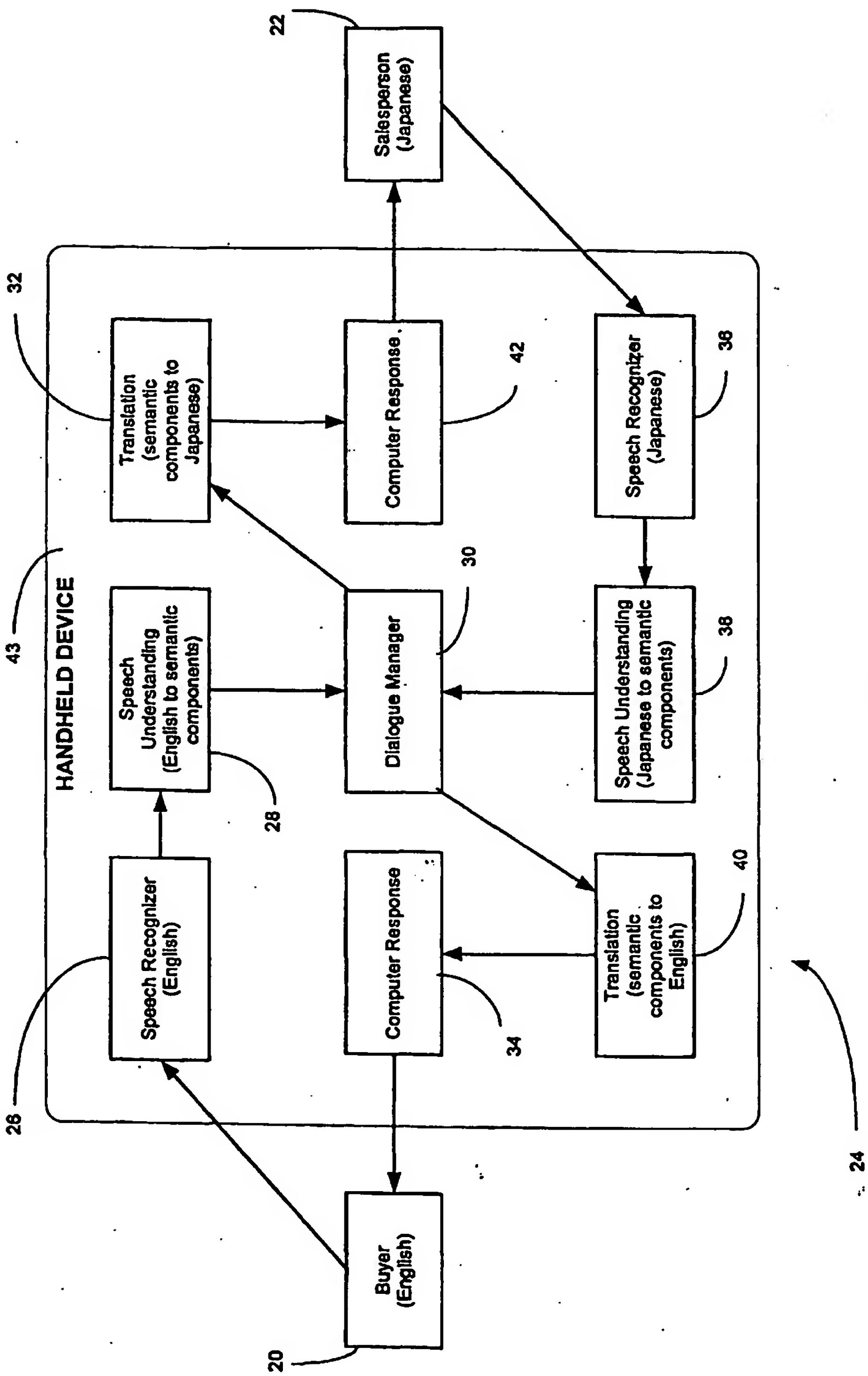

HANDHELD DEVICE
Buyer (English)
Salesperson (Japanese)
Speech Recognizer (English)
Speech Understanding (English to semantic components)
Translation (semantic components to Japanese)
Dialogue Manager
Computer Response
Computer Response
Speech Recognizer (Japanese)
Speech Understanding (Japanese to semantic components)
Translation (semantic components to English)
20
22
24
26
28
30
32
34
36
38
40
42
43

FIG. 1

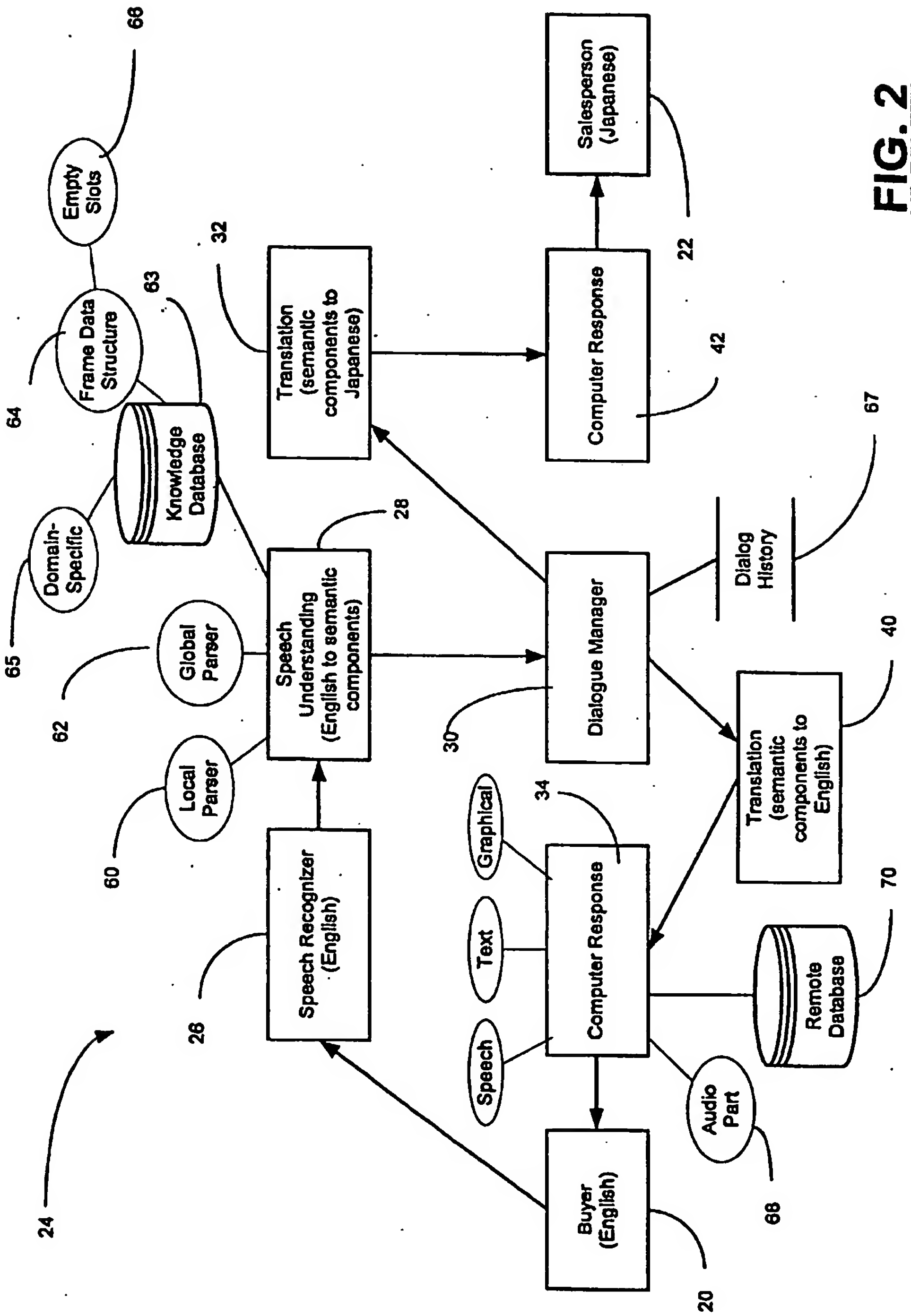

Buyer (English)
Speech Recognizer (English)
Local Parser
Global Parser
Speech Understanding (English to semantic components)
Domain-Specific
Knowledge Database
Frame Data Structure
Empty Slots
Translation (semantic components to Japanese)
Dialogue Manager
Dialog History
Translation (semantic components to English)
Computer Response
Speech
Text
Graphical
Audio Part
Remote Database
Salesperson (Japanese)
20
22
24
26
28
30
32
34
40
42
60
62
63
64
65
66
67
68
70

FIG. 2

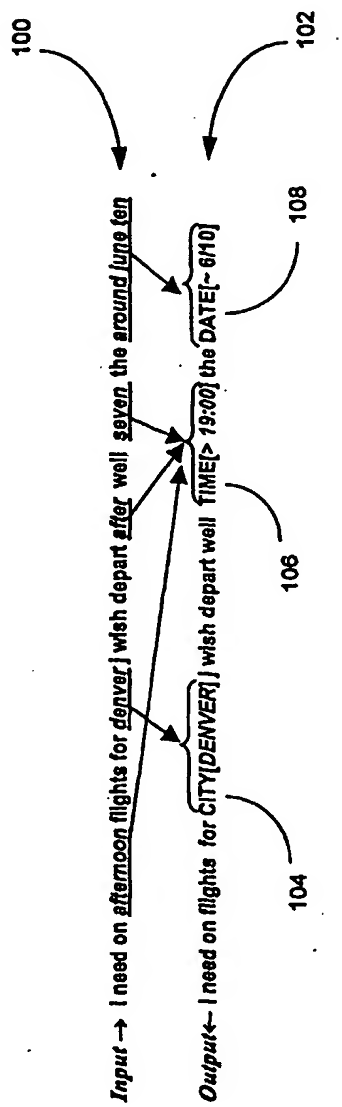

100
102
Input → I need on afternoon flights for denver I wish depart after well seven the around june ten
Output← I need on flights for CITY[DENVER] I wish depart well TIME[> 19:00] the DATE[~ 6/10]
104
106
108

FIG. 3

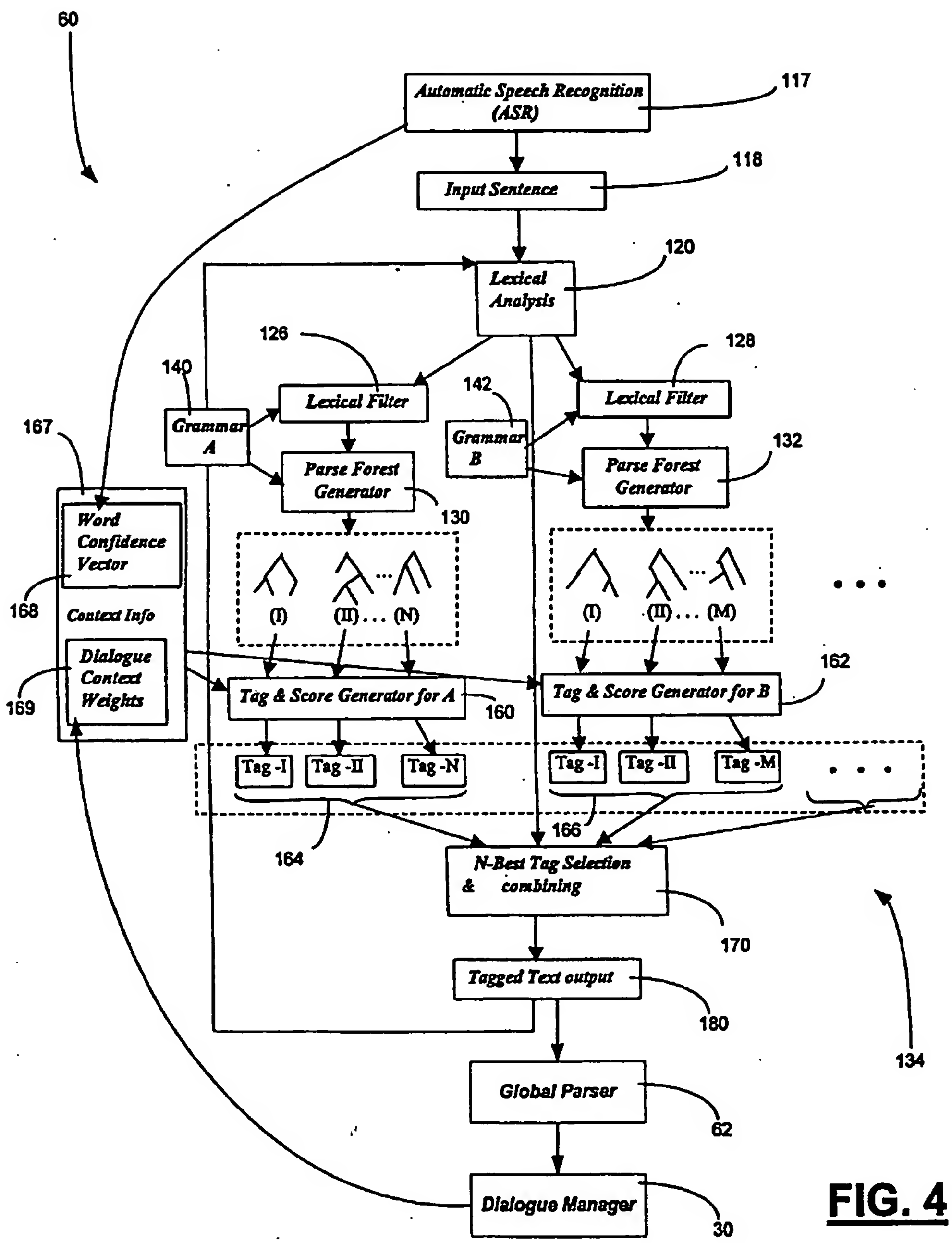

60
Automatic Speech Recognition (ASR)
117
Input Sentence
118
Lexical Analysis
120
126
128
140
Grammar A
Lexical Filter
142
Grammar B
Lexical Filter
167
Parse Forest Generator
130
Parse Forest Generator
132
Word Confidence Vector
168
Context Info
(I)
(II) . . . (N)
(I)
(II) . . . (M)
Dialogue Context Weights
169
Tag & Score Generator for A
160
Tag & Score Generator for B
162
Tag -I
Tag -II
Tag -N
Tag -I
Tag -II
Tag -M
164
166
N-Best Tag Selection & combining
170
Tagged Text output
180
134
Global Parser
62
Dialogue Manager
30

FIG. 4

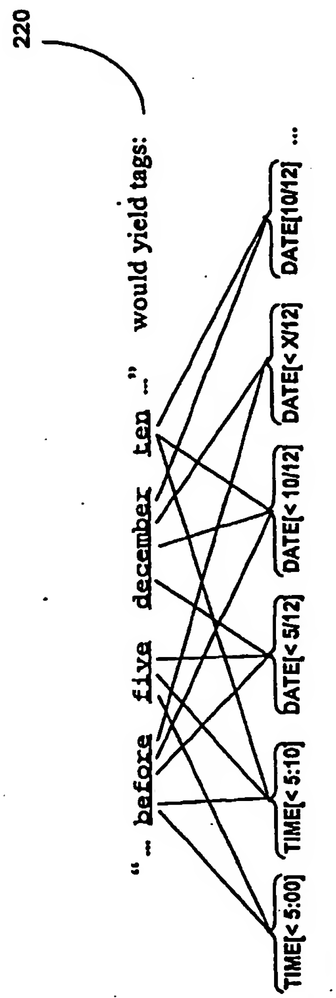

220
"... before five december ten ..." would yield tags:
TIME[< 5:00]
TIME[< 5:10]
DATE[< 5/12]
DATE[< 10/12]
DATE[< X/12]
DATE[10/12]
...

FIG. 5

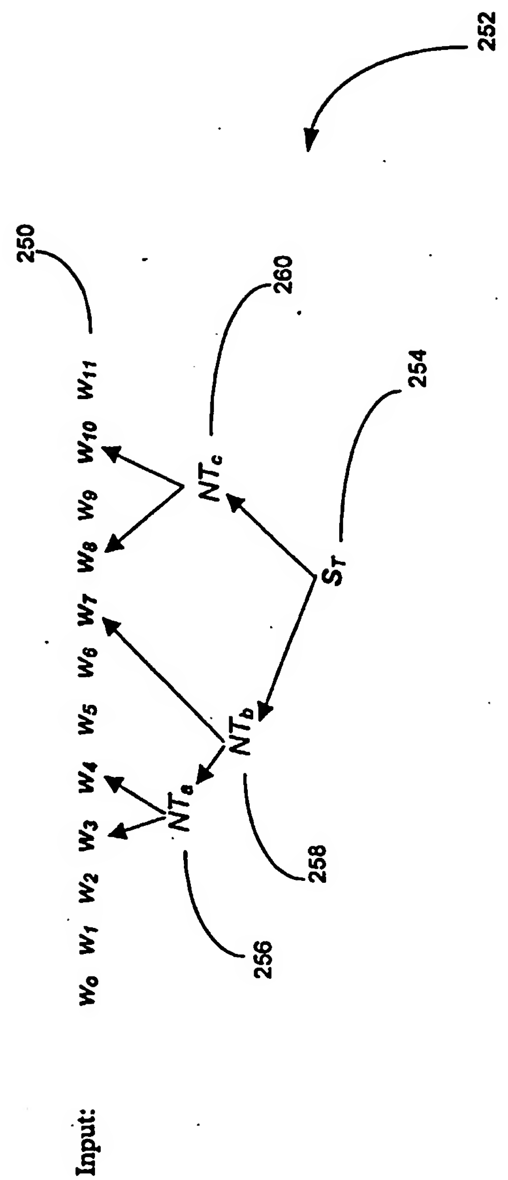
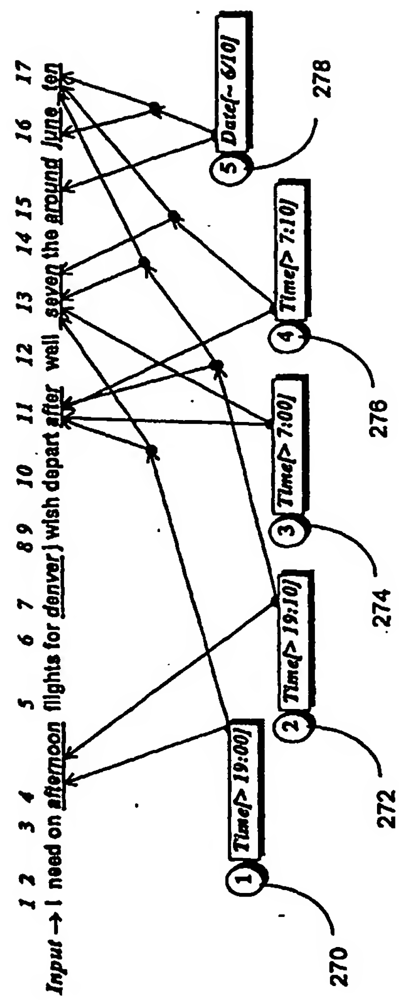
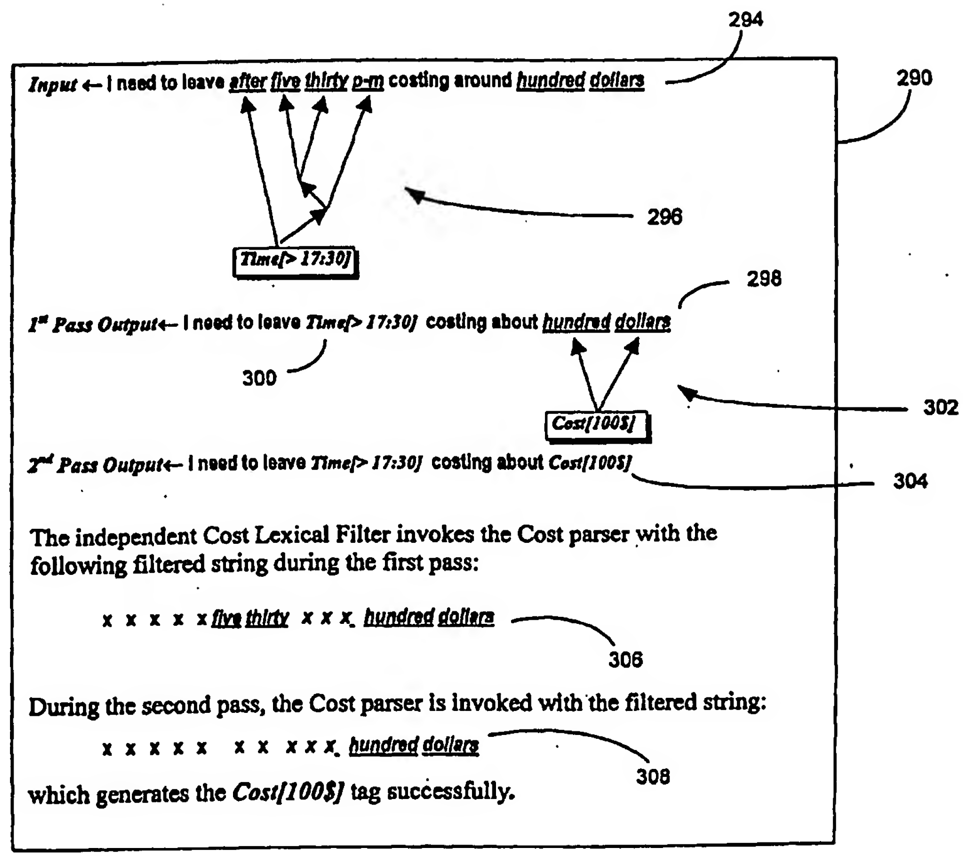

Input:
W_0 W_1 W_2 W_3 W_4 W_5 W_6 W_7 W_8 W_9 W_{10} W_{11}
NT_a
NT_b
NT_c
S_T
250
252
254
256
258
260

FIG. 6



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Input → I need on afternoon flights for denver) wish depart after well seven the around june ten
1 Time[> 19:00]
2 Time[> 19:10]
3 Time[> 7:00]
4 Time[> 7:10]
5 Date[~ 6/10]
270
272
274
276
278

FIG. 7



Input ← I need to leave after five thirty p-m costing around hundred dollars
294
290
296
Time[> 17:30]
298
1st Pass Output← I need to leave Time[> 17:30] costing about hundred dollars
300
302
Cost[100$]
2nd Pass Output← I need to leave Time[> 17:30] costing about Cost[100$]
304
The independent Cost Lexical Filter invokes the Cost parser with the following filtered string during the first pass:
x x x x x five thirty x x x hundred dollars
306
During the second pass, the Cost parser is invoked with the filtered string:
x x x x x x x x x x hundred dollars
308
which generates the Cost[100$] tag successfully.

FIG. 8

```
* COST.
COST =      C_Core.
C_Core = C_Gen |
         C_Phr |
         C_Qualified |
         C_Interval  |
         X C_Core |
         C_Core X.
C_Gen =  C_Num |
         C_Num  C_Currency.
C_Num  = C_Thousands C_Hundreds C_Tens |
         C_Thousands C_Hundreds |
         C_Thousands |
         C_Hundreds C_Tens |
         C_Hundreds |
         C_Tens |
         X C_Num.
C_Thousands = C_Tens c_thousand |
              c_thousand.
C_Hundreds  = C_Tens c_hundred |
              c_hundred.
C_Tens =        c_num |
              c_num c_numToTen.
C_Currency    = c_yen |
              c_dollar |
              X C_Currency.
C_Phr =  c_cheapest | c_least | c_least
c_expensive.
C_Qualified =    c_qualifier C_Gen.
C_Interval =     c_between C_Gen C_Gen.
X = x |  X x.
XX = x x | x.
c_yen: yen yens.
c_dollar:  dollar dollars.
c_cheapest:  cheapest.
c_least:     least.
c_expensive: expensive.
c_qualifier: under below less.
c_between:   between.
c_thousand:  thousand.
c_hundred:   hundred.
c_num: one two three four five six seven
eight nine ten eleven
     twelve thirteen fourteen fifteen
sixteen seventeen
     eighteen nineteen twenty thirty forty
fifty sixty seventy
     eighty ninety.
c_numToTen: one two three four five six
seven eight nine.
x.
```

320

324

328

FIG. 9

```
→ flights under five hundred dollars ←          400
     0       1     2    3       4
* COST_0_5.
 x_0_1: "x".                                     424
 X_0_1 = x_0_1.                                  420
408 c_qualifier_1_2: "under".
 c_numToTen_2_3: "five".
 c_num_2_3: "five".
404 C_Tens_2_3 = c_num_2_3.
 C_Num_2_3 = C_Tens_2_3.
 C_Gen_2_3 = C_Num_2_3.
 C_Qualified_1_3 = c_qualifier_1_2 C_Gen_2_3.
 C_Core_1_3 = C_Qualified_1_3.
 C_Core_0_3 = X_0_1 C_Core_1_3.
 COST_0_3 = C_Core_0_3.
 c_hundred_3_4: "hundred".
 C_Hundreds_2_4 = C_Tens_2_3 c_hundred_3_4.
 C_Num_2_4 = C_Hundreds_2_4.
 C_Gen_2_4 = C_Num_2_4.
 C_Qualified_1_4 = c_qualifier_1_2 C_Gen_2_4.
 C_Core_1_4 = C_Qualified_1_4.
 C_Core_0_4 = X_0_1 C_Core_1_4.
437 COST_0_4 = C_Core_0_4.
 c_dollar_4_5: "dollars".
 C_Currency_4_5 = c_dollar_4_5.
 C_Gen_2_5 = C_Num_2_4 C_Currency_4_5.
 C_Qualified_1_5 = c_qualifier_1_2 C_Gen_2_5.    434
 C_Core_1_5 = C_Qualified_1_5.                   430
416 C_Core_0_5 = X_0_1 C_Core_1_5.
412 COST_0_5 = C_Core_0_5.

Parse Forest "flights under five hundred
                  dollars"
```

FIG. 10

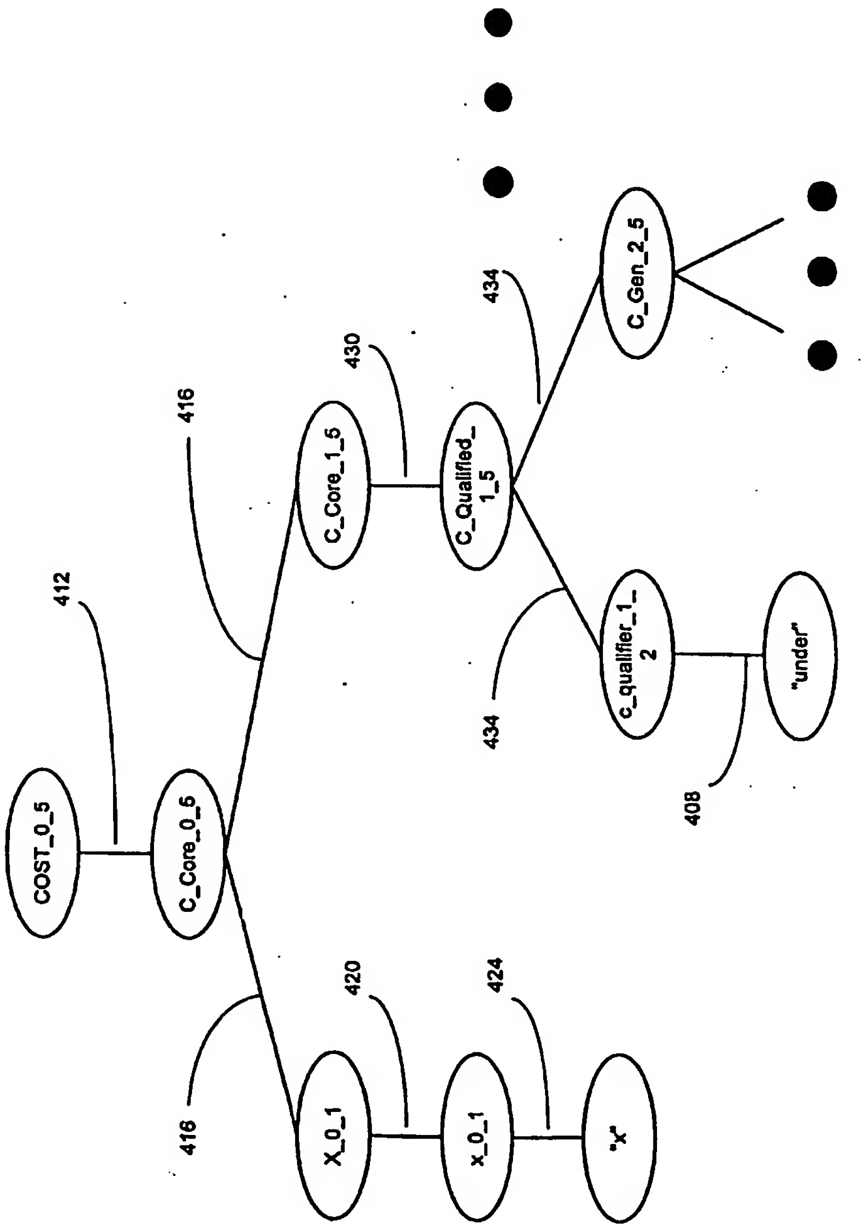

COST_0_5
C_Core_0_5
412
416
C_Core_1_5
430
C_Qualified_
1_5
434
C_Gen_2_5
c_qualifier_1_
2
434
"under"
408
416
X_0_1
420
x_0_1
424
"x"

FIG. 11

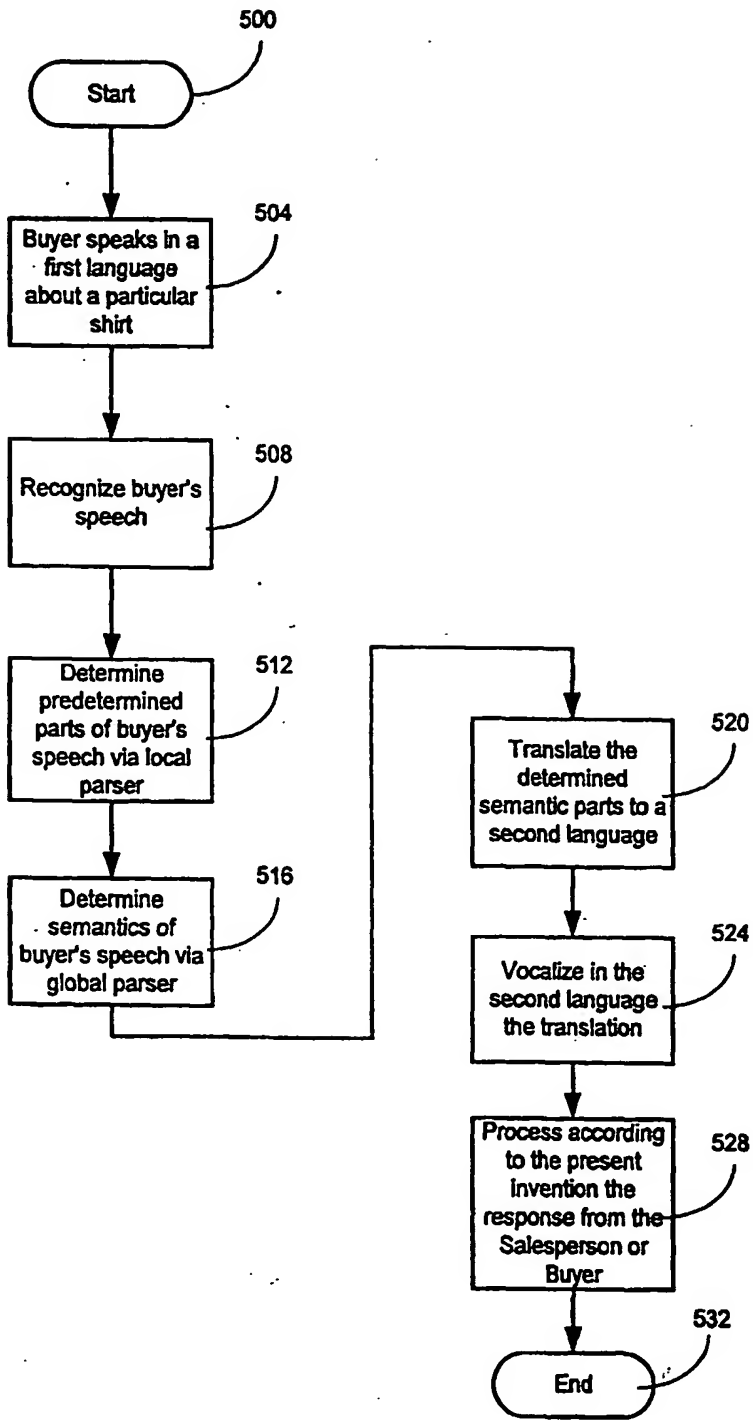

500
Start
504
Buyer speaks in a first language about a particular shirt
508
Recognize buyer's speech
512
Determine predetermined parts of buyer's speech via local parser
516
Determine semantics of buyer's speech via global parser
520
Translate the determined semantic parts to a second language
524
Vocalize in the second language the translation
528
Process according to the present invention the response from the Salesperson or Buyer
532
End

FIG. 12

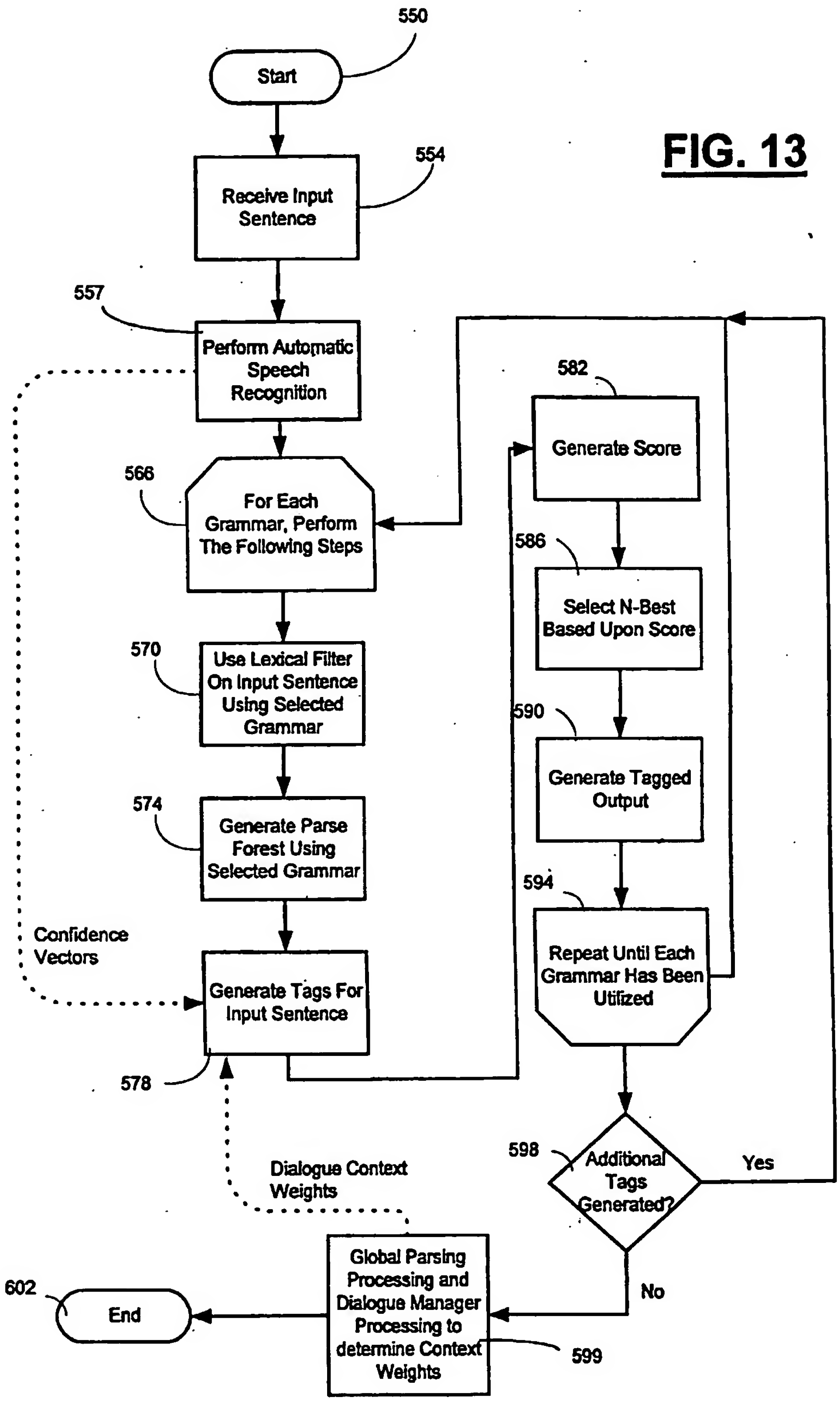

550
Start
554
Receive Input Sentence
557
Perform Automatic Speech Recognition
566
For Each Grammar, Perform The Following Steps
570
Use Lexical Filter On Input Sentence Using Selected Grammar
574
Generate Parse Forest Using Selected Grammar
Confidence Vectors
Generate Tags For Input Sentence
578
582
Generate Score
586
Select N-Best Based Upon Score
590
Generate Tagged Output
594
Repeat Until Each Grammar Has Been Utilized
598
Additional Tags Generated?
Yes
No
Dialogue Context Weights
Global Parsing Processing and Dialogue Manager Processing to determine Context Weights
599
602
End

FIG. 13